Design, Verification, and Forensic Correlation of Composite Yacht Structures

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Presentation Overview

- Background/Project Intro and Scope
- Analysis Techniques
- Experimentation
- Forensic Correlation
  - Deck Panel
  - Masts
  - Hulls
- Suggestions

Background

- Team Dennis Conner's America's Cup Campaign 2003
  - Relatively small program
- Private lightweight cruiser/racer
- Both "high performance but risk averse"

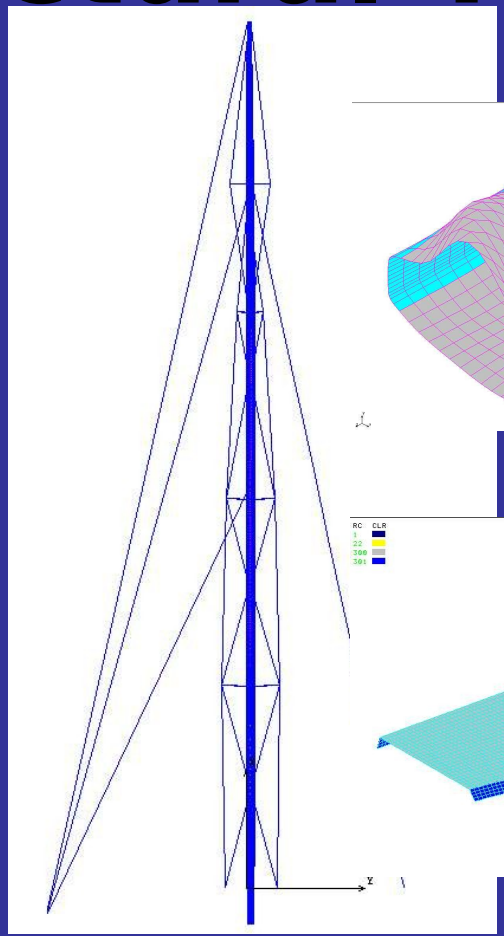
- Materials:
- TDC
  - Prepreg carbon/epoxy uni (100° or 135°, 1 or 3 atm)
  - Aluminum honeycomb
- S/V Cascadia
  - Wetpreg carbon/epoxy, latent cure (~45°, 1 atm)
  - Cedar/balsa

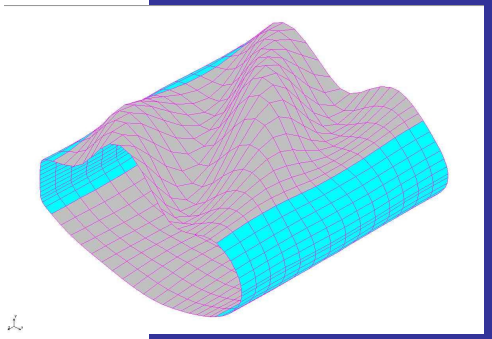
Design Methodology

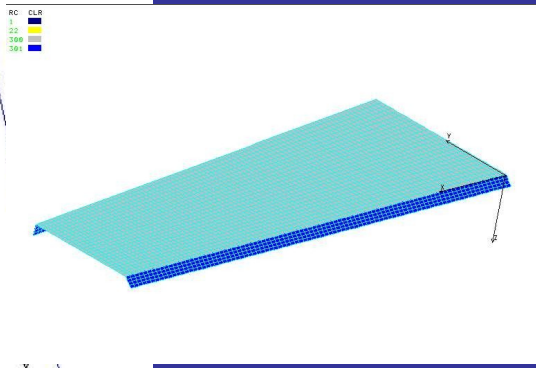
1. **Risk Analysis**
   - **All team members**
2. **Uncertainty Identification**
3. **Targeted Performance and Structural Evaluation (FOS=1 to 8+)**

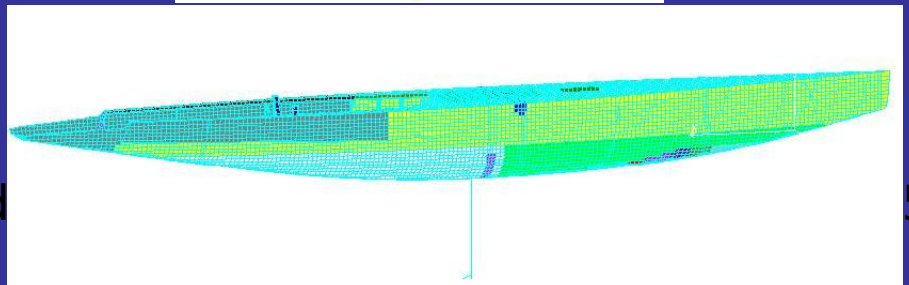
Primary Structural Tool

- COSMOS/M finite element analysis (SRAC)
- Linear (Mindlin and DiScuiva) Laminated Shell Elements & user-defined
- Nonlinear Material and Geometry
- Tsai-Wu and user-defined (Hashin) failure criteria
- Global/Local rig and hull
- Loads from FLOW (rig) or SPLASH

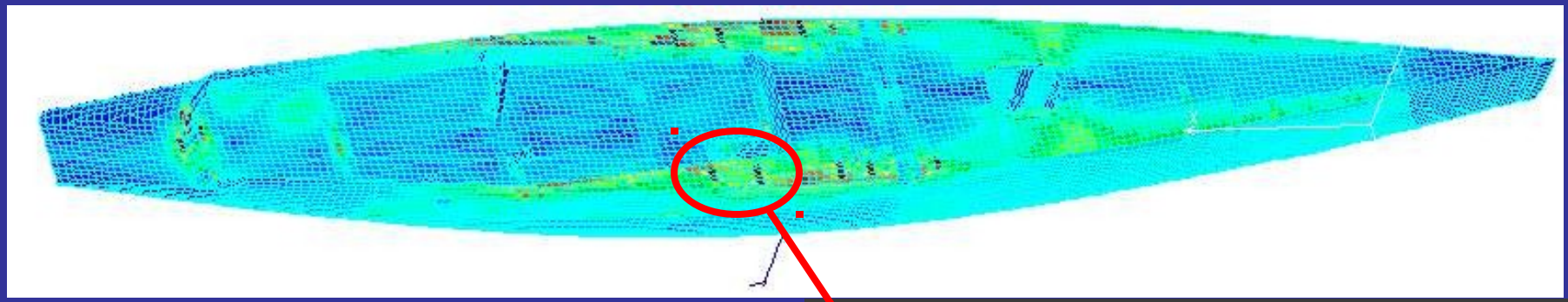




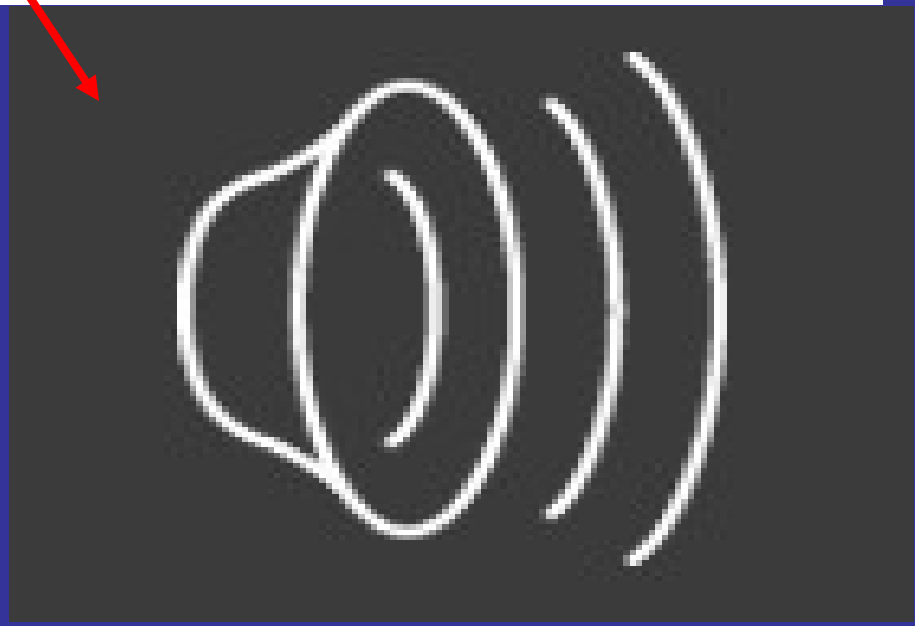




Deck Panel Test
Compression

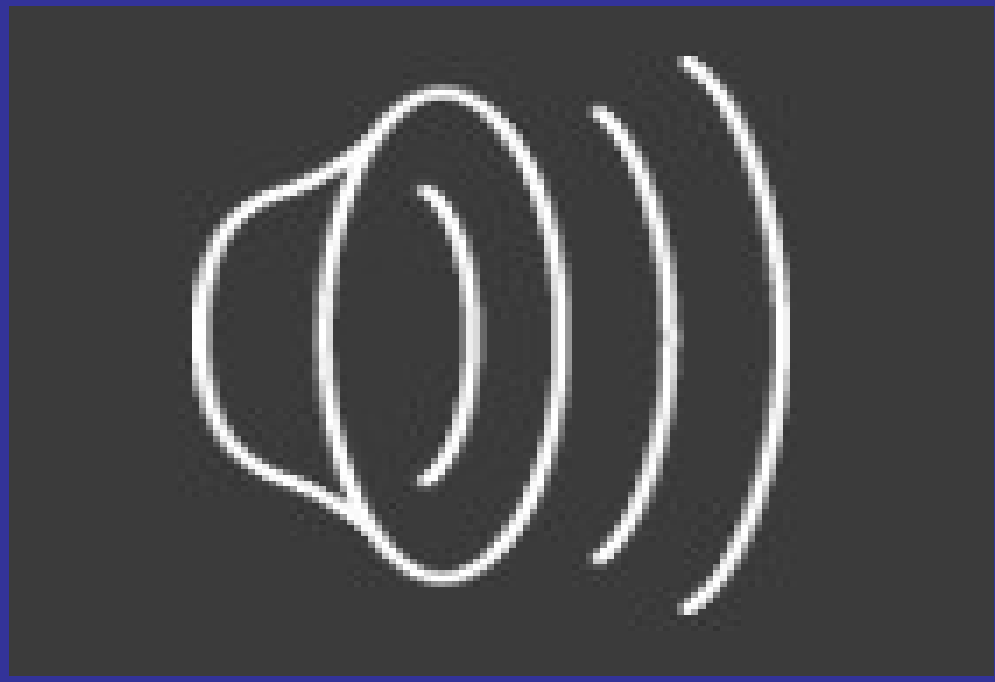


- Duplicated critical part
- Ply stacking investigated
- Non-traditional stack judged best
- FEA 180%/112% of test



Rig Test
Compression and Impact

- Wall buckling limited
- “Risky” and “Likely”
- Weight critical
- Resin content effect evaluated
- Sidewall thickness decreased from 6 to 3 mm
- 72% to 89% of FEA



185 Volvo Station Wagons!

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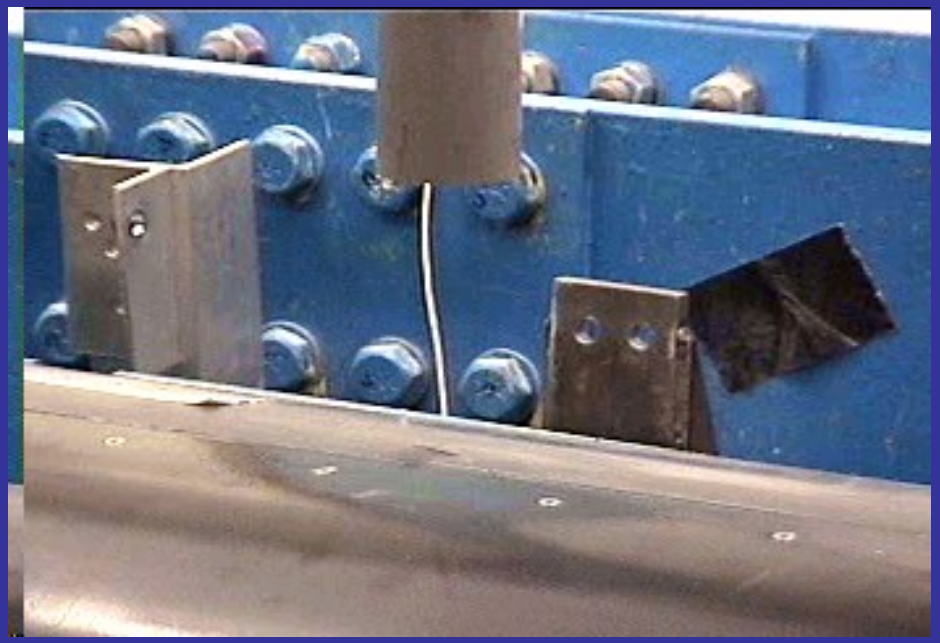
Rig Test
Compression and Impact

- "Highest Consequence" Event Simulated, Load & Geometry
- Adopted "damage tolerant" design (resin, stacking sequence)
- Both passed, 1 punctured



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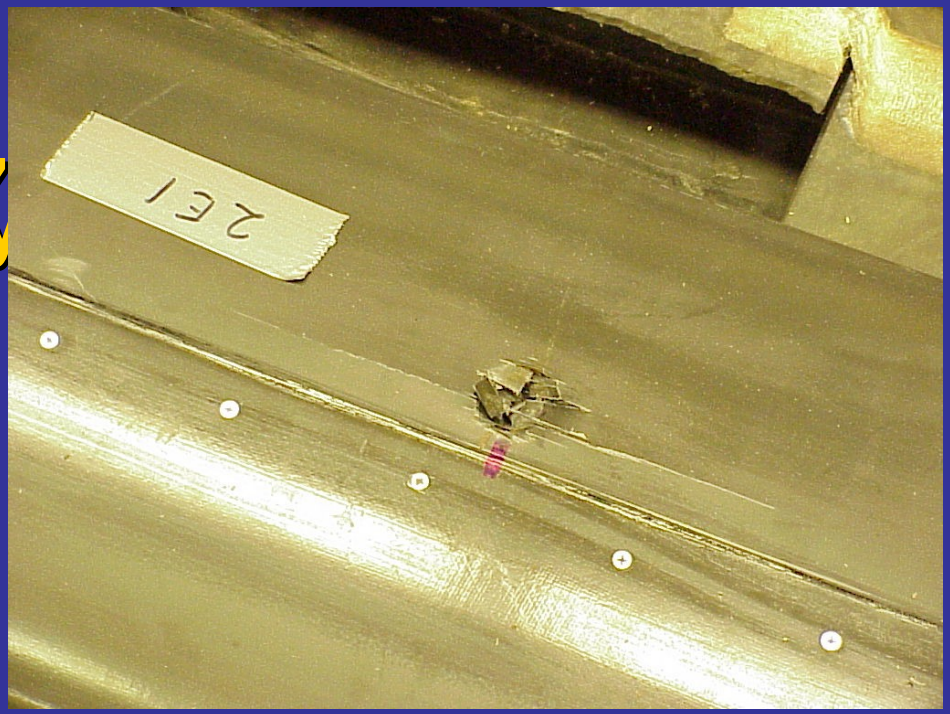


Forensic Correlation Mast #1

- Failure after 13 hours of use
- Winds of 14-17 kts at the time (23 the day before but less tension)
- 6 possible failure scenarios, all evaluated by FEA, one had 1.0 FOS.

Three minutes before failure

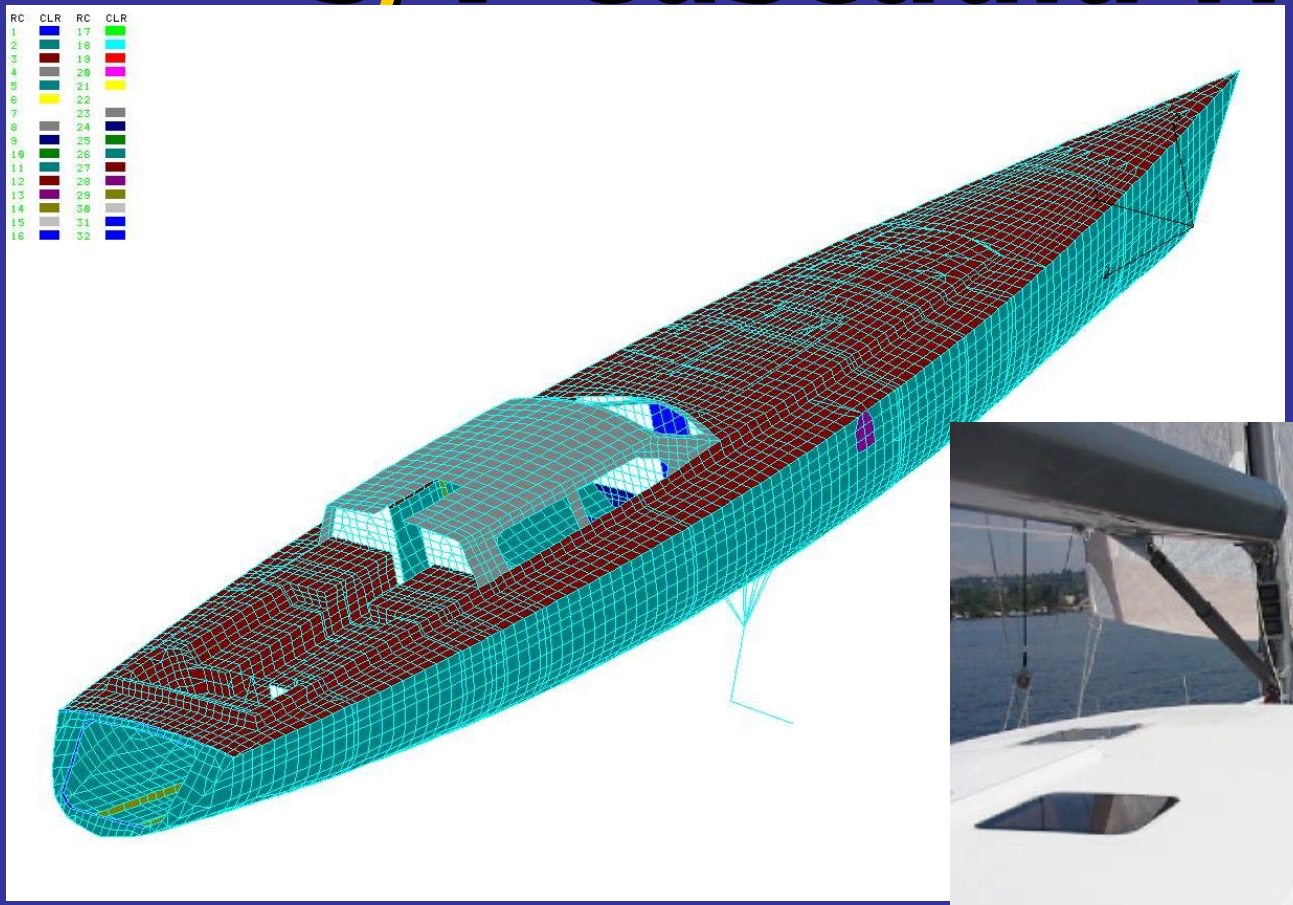
Rig (Reactive) Modifications

- Mast 2: extra reinforcement
- Mast 3: improved QA
- Mast 4: same as Mast 1
- Mast 5: reduced structure

IACC USA-77 Hull

- Sank after “rudder failure”, traced to poor QA and bad communication
- FEA identified possible damage spots
- All but one found
- Assisted in repairs
- Vessel regained competitive status

S/V Cascadia Hull



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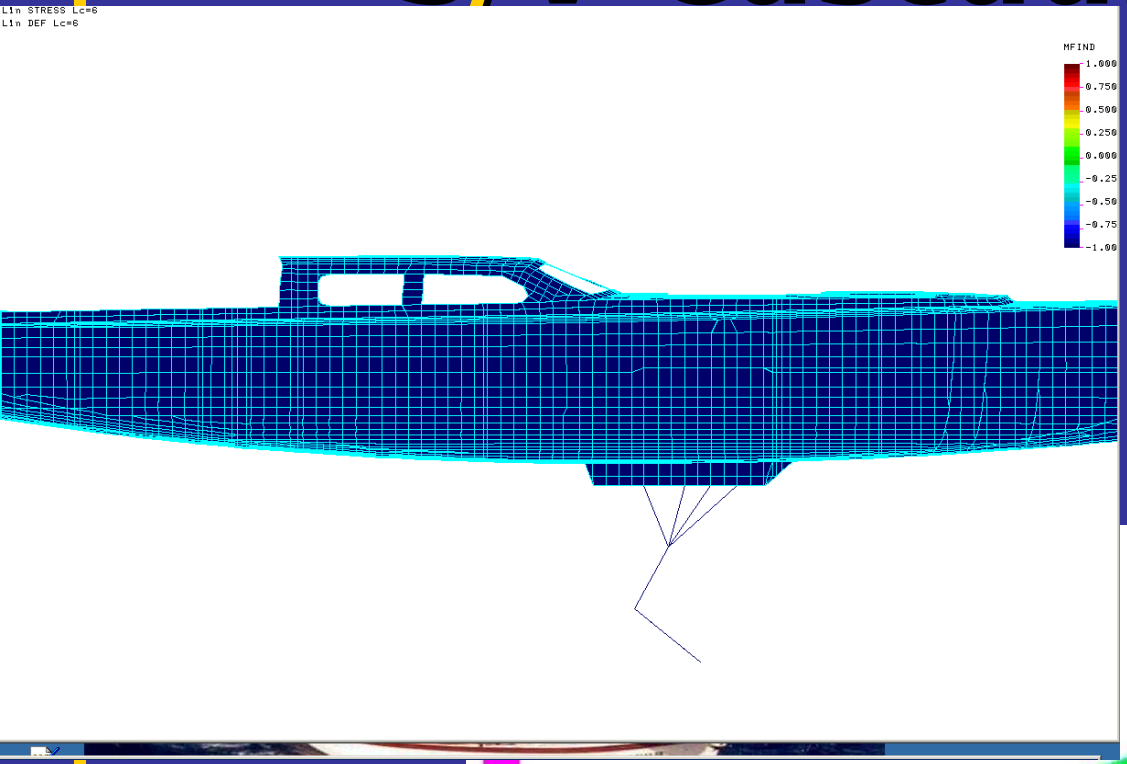
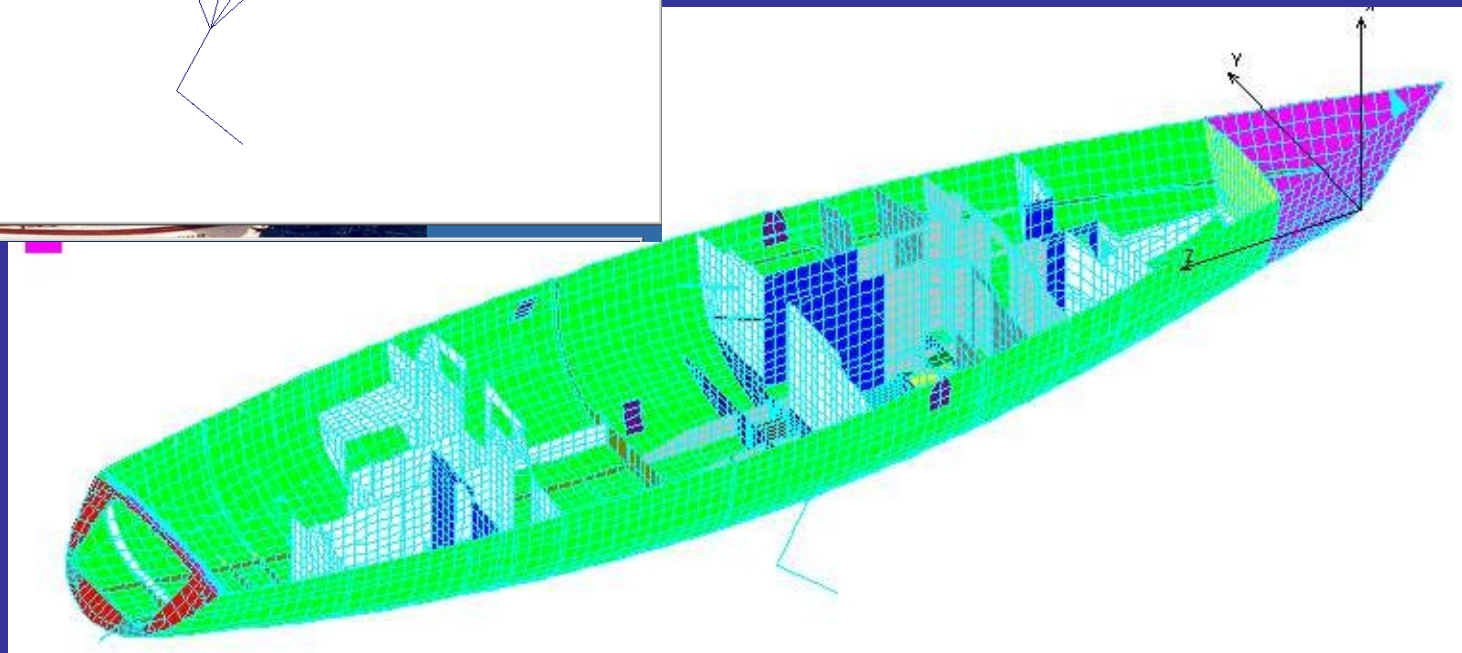
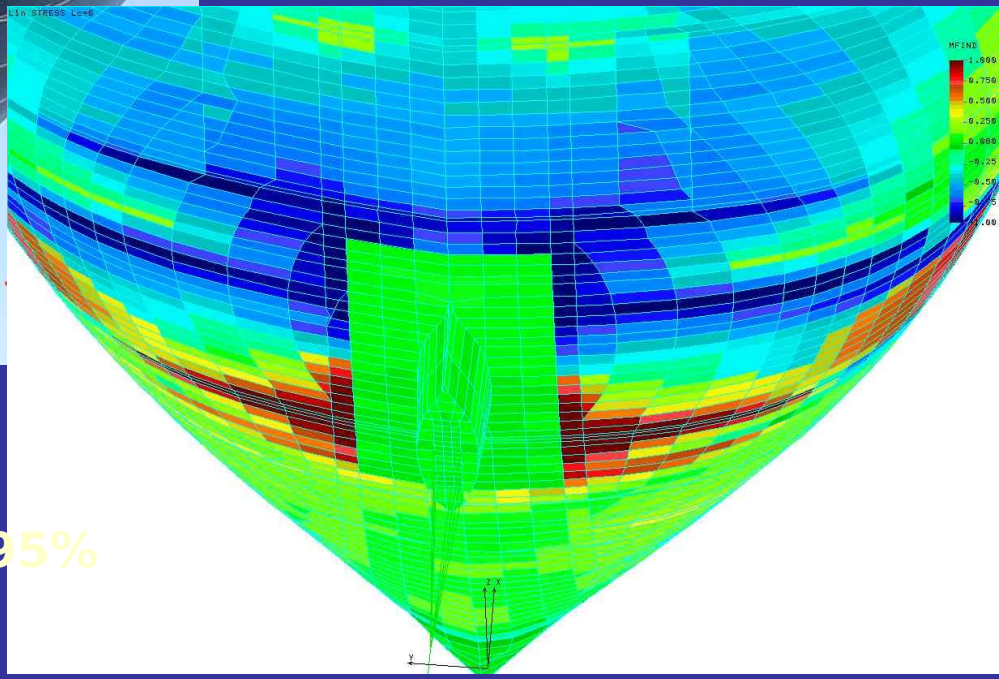




S/V Cascadia Hull

Outer Ply Factor of Safety



Correlation better than 95%

Conclusions

- Matching boundary conditions is critical to FEA accuracy
- Maintain global FEA models (w/ as-builts)
- Initial ultrasound mapping is beneficial
- QA is critical, but often under-stressed in modern high-tech, low FOS applications
- Hopefully no further research!